Lung volume reduction surgery beyond the NETT selection criteria

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Abstract: Lung volume reduction surgery (LVRS) for symptomatic patients with advanced emphysema was proven to be successful in a large randomized multi-center trial (NETT) and in several smaller randomized single center trials. This evidence primarily concerns patients with heterogeneous, upper-lobe predominant emphysema and low exercise tolerance within certain selection criteria regarding lung function values. As the most important effect of LVRS is generated by reducing the hyperinflation, even patients with homogeneous emphysema morphology profit from the procedure. Simultaneously, by removing distended and functionless areas in heterogeneous emphysema, also patients with seriously impaired diffusion capacity, moderate pulmonary arterial hypertension, a history of previous LVRS and alpha-1-antitrypsin-deficiency (AATD) can be considered as candidates for (re-)-LVRS. This article summarizes indications for LVRS in these various subtypes of emphysema patients.

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Review Article

Postoperative complications and management after lung volume reduction surgery

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Abstract: The aim of lung volume reduction surgery (LVRS) for patients suffering from severe emphysema is to improve lung function and palliate dyspnea. Careful patient selection in a multidisciplinary approach in a high-volume center is mandatory for a successful outcome. Pulmonary complications including air leak and pneumonia as well as cardiac complications are the most common complications after LVRS. The following article will focus on most common complications observed after LVRS and review the management strategies to improve surgical outcome.

Keywords: Emphysema; lung volume reduction surgery (LVRS); postoperative complications

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Introduction

The aim of lung volume reduction surgery (LVRS) for patients suffering from severe emphysema is to improve lung function and quality of life by reducing dyspnea. For carefully selected patients with severe emphysema and hyperinflation, LVRS can be performed as a safe and effective treatment in a specialized high-volume center.

Emphysema and chronic bronchitis are two conditions that define chronic obstructive pulmonary disease (COPD). Smoking is the leading cause of COPD worldwide (1). Treatment of COPD may slower progression but cannot reverse damage to the parenchyma. In addition to medical therapy, surgical lung volume reduction was shown to improve lung function and quality of life (2). The National Emphysema Treatment Trial (NETT) was the first randomized multi-center trial comparing LVRS with medical treatment in patients with severe emphysema. Compared to the medically treated group, the LVRS group (>500 patients), had a much more significant improvement of lung function, walking distance, quality of life and even survival (2). Besides lung-transplantation, LVRS remains one of the most valuable treatment-options for patients suffering from severe emphysema. Careful patient selection in a multidisciplinary approach is mandatory for best possible outcome. By resection of the most destroyed areas, hyperinflation of the lung can be reduced and in combination with reshaping of the diaphragm lung function will improve (3).

Over the past decade, in specialized centers video-assisted-thoracoscopic approach has become gold standard for LVRS (4). First description of bilateral thoracoscopic LVRS was reported in 1996 (5). At our institution, we started our LVRS-program in 1993 performing a bilateral thoracoscopic approach, which was the first world wide. In the majority, we performed bilateral one-staged LVRS. In 1996 McKenna and colleagues reported comparable morbidity, mortality and mean length of stay for unilateral and bilateral procedures but substantially better benefit for bilateral resection (6).

Homogenous and heterogeneous emphysema causes hyperinflation of the lung and therefore, patients with both entities can benefit from LVRS. However,

best evidence exists for heterogeneous upper-lobe predominant emphysema (2). By removing the most affected parenchyma and therefore reducing hyperinflation, the flattened diaphragm regains its dome-like shape. This increases diaphragmatic muscle strength and increases lung function. This is why measuring hyperinflation by body-plethysmography is one of the key factors for patient selection. However, as reported in the NETT, distribution-heterogeneity was demonstrated as the most important selection criterion for LVRS. Patients with homogenous emphysema disease show a higher risk for morbidity and mortality after LVRS (2). Furthermore, unacceptable high mortality rates have been demonstrated in subgroups of patients in the NETT trial: patients with very low forced expiratory volume in 1 second (FEV1 <20% predicted) and homogenous emphysema and/or a low diffusion capacity [diffusing capacity for carbon monoxide (DLCO) <20% predicted] (2).

Postoperative complications and management

To minimize postoperative complications after LVRS, the thoracic surgery unit should perform a certain amount of cases a year. Although there is no data on the exact amount of operations per year and the overall experience, in analogy to technical demanding procedures as video-assisted thoracoscopic surgery (VATS)-lobectomy, a minimal experience of 30 procedures and an annual number of 20 should be required. Furthermore, careful patient selection after multidisciplinary discussion is mandatory. Several factors have been reported to increase morbidity and mortality: Advanced age, hypercapnia, cachexia, homogenous distribution of emphysema, pulmonary hypertension, low diffusion capacity, low forced expiratory volume, repeated hospitalizations due to recurrent infection and patients with steroid therapy (2,7-11). Importantly, smoking increases postoperative morbidity and mortality (12), therefore patients ideally stop smoking at least 6 to 12 weeks prior to LVRS (13). In the NETT, a four months non-smoking status was required prior to surgery (2). In our institution, patients undergoing any kind of interventional treatment for emphysema, need to have quit smoking at least six months before.

To achieve the best postoperative outcome, multidisciplinary patient care, including thoracic surgeons, anesthesiologists, pulmonologists, physiotherapy and nursing staff is mandatory. Due to frequently associated comorbidities in COPD patients, preoperative optimization of medical therapy including pulmonary rehabilitation might reduce incidence of postoperative complications (14).

The National Emphysema Trial documented 91% of patients without intraoperative complications but around 60% faced at least one postoperative complication. In total of 41.3% of patients showed pulmonary morbidity after surgery and about 20% had major cardio-vascular morbidity (2).

Most frequent complications after LVRS are of pulmonary origin, especially air leak. Failure for early extubation resulting in prolonged ventilation with need for tracheostomy and pneumonia are extremely rare. In addition, cardiac complications including arrhythmias, myocardial infarction and pulmonary embolus have been frequently reported. Gastro-intestinal complications may also be increased in LVRS patients (15). In the following chapter, we will focus on the different types of postoperative complications, their prevention and management.

Pulmonary morbidity

Air leak

Air leak is the most common complication after LVRS. Prolonged air leak is defined as an air leak lasting more than 5–7 days after surgery. Ciccone and colleagues reported that up to 45.2% of patients present prolonged air leak after LVRS (16). In the NETT data, there was no significant difference between median sternotomy and VATS approach regarding the occurrence of air leaks (2). The use of inhaled steroids, impaired lung function (lower diffusion capacity), homogenous emphysema and most important the degree of pleural adhesions are primary factors influencing prevalence and duration of air leak (17). As reported in the NETT, reoperation due to persistent air leak was required in up to 5% of patients (2). Subcutaneous emphysema was increased in patients after a VATS approach compared to patients after a median sternotomy, occurring in around 5 to 10% (18).

Prevention of air-leaks would be the most efficient way to reduce several complications. In order to avoid air leaks during surgery, adapted techniques play an important role. The use of buttressed staple lines was shown to reduce the incidence of air leaks and the time to remove the chest tube (19). In addition, autologous fibrin sealant can decrease the incidence of prolonged air leak and duration of chest tube after LVRS (20). However, a Cochrane systematic review of 1,642 patients concluded in a non-recommendation for routine use of surgical sealants (21). Important prevention strategies include minimizing dissection within the

fissures, avoiding overlapping parenchymal staples lines or excessive resections. If pleural adhesions are present, careful dissection has to be performed, as emphysema lung parenchyma is very fragile. If the video-assisted thoracoscopic approach does not ensure proper adhesiolysis, we recommend conversion to thoracotomy in order to lessen parenchymal trauma. At the end of resection, the lung should be carefully re-inflated under vision control to assure the remaining lung is expanding completely and reaches the parietal pleura. Due to the contact of both visceral and parietal pleura, superficial air leaks will heal faster and drainage time is reduced. When re-inflating the lungs and during the period of extubation, inspiratory pressures should be as low as possible. Switching from double-lumen-tube to laryngeal mask (LAMA) was shown to prevent coughing with height pressure on stapler-lines during extubation. Early extubation in the operation theatre is a key factor to reduce occurrence and extent of air leak.

Despite all these precaution-maneuvers, around 30% of all our patients after LVRS present with prolonged air leak and around 10% of them will need revision surgery for fistula closure. The relatively high incidence in our cohort is probably due to the more aggressive approach when prolonged air leak is associated with progressive subcutaneous emphysema.

Whether or not the chest drain should be held under permanent suction and what level of suction was addressed in several studies. There are no data about length and strength of suction in LVRS-patients. If tolerated by the patient, the chest drain might be connected to a Heimlich valve without suction in order to increase patient mobility even if a small amount of air leak is present. Thus, length of hospital stay can be reduced by discharging patients with chest tube in place. The median postoperative length of stay in our patient cohort is 11 days, the literature shows values between 10 to 14 days (22-24).

Pneumonia

Pneumonia is considered the second most common pulmonary complication after LVRS. In the NETT, about 18% of patients developed pneumonia postoperatively (2). Failure to early extubation and necessity for tracheostomy have been reported in 3.9% and 8.2%, respectively (2). In order to minimize infectious complications, at our institution prophylactic antibiotic therapy is started one hour before surgery and continued until the last drain has been removed. Due to marginal pulmonary capacity in these fragile group of patients, our approach to antibiotic therapy is rather liberal. If pneumonia occurs, antibiotic therapy needs to be tailored to microbiological findings if available. Up to today, there is no perioperative evidence-based antibiotic management protocol available for LVRS patients. Postoperative early extubation and early mobilization are important in order to prevent infectious complications. Inhalation therapy and the use of incentive spirometry should be instructed before the procedure and continued immediately after surgery. Therefore, careful pain management with epidural anesthesia to enable early mobilization and respiratory therapy is fundamental to prevent side effects of opioid treatment (sleepiness with risk of aspiration) and pneumonia (25). In order to ensure patient mobility and reduce the risk of catheter complications, epidural catheter should be removed within 2 to 3 days postoperatively. The NETT reported that 0,8% of patients developed epidural catheter complications (2).

Cardiac morbidity

Cardiac complications including arrhythmia, myocardial infarction and pulmonary emboli are reported after LVRS in analogy to other thoracic interventions. Arrhythmia is considered as the most frequent cardiac complication after LVRS. Within the NETT around 22% of patients developed postoperative arrhythmia requiring further medical therapy (2). Myocardial infarction and pulmonary embolus were reported within 1 and 0.8% respectively (2).

Arrhythmia

Atrial arrhythmia is the most common but rare arrhythmia after LVRS. Postoperative fluid overload, hypoxia and atelectasis can cause atrial arrhythmias. Careful postoperative fluid management and preventing fluid overload by use of diuretics can avert the occurrence of postoperative arrhythmias. Generally, in normo-frequent and asymptomatic patients, temporary adjustment of anticoagulation treatment is indicated. If patient shows clinical signs of depletion either pharmacological agents such as calcium channel blockers as well as amiodarone are used, or cardioversion is indicated.

Thrombo-embolic disease

To prevent thrombo-embolic disease, prophylactic anticoagulation with unfractionated heparin is started

postoperatively in our institution. As reported by Geerts and colleagues, obesity, age over 40 years, medical history of previous thromboembolism, varices and estrogen use are important risk factors for venous thromboembolism (26). After bilateral LVRS, once chest drains are removed, we recommend therapeutic anticoagulation for 3 months following surgery. Oral anticoagulation can either be established with a vitamin-K antagonists or new oral factor-Xa-inhibitors such as rivaroxaban (Xarelto®). For vitamin-K antagonists, close monitoring and dose adjustments are necessary in order to obtain therapeutic anticoagulation, therefore we generally prefer to establish oral anticoagulation with factor-Xa-inhibitors. There is no recommendation for the use of oral anticoagulation after bilateral LVRS patients up to this date.

Gastro-intestinal morbidity

As reported by Naunheim and colleagues' gastro-intestinal complications after LVRS occur in about 6% of the patients (27). Diabetes, the use of corticosteroids as well as a higher number of pain medication have been documented to increase gastro-intestinal complications after LVRS (15). The occurrence of postoperative Ileus or Ogilvie's syndrome might be related due to epidural catheter for pain relief postoperatively. Narcotic analgesics may increase the risk of gastro-intestinal depression. Due to these known adverse events, analgetic therapy should be selected carefully, particularly for patients who are of higher risk for gastro-intestinal complications.

Conclusions

Careful patient selection and anticipatory multidisciplinary patient care in a high-volume center are major keys to ensure the best postoperative outcome after LVRS. As reported in the NETT lung volume reduction can improve quality of life with low postoperative mortality and acceptable morbidity. In our institution, 30-day mortality rates were reported below 3% after thoracoscopic LVRS (28) in the past and is now below 0.5%.

Preoperative preparation, vigilant surgical technique and anticipation of potential postoperative complications are mandatory for successful LVRS.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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